Embodiments of the present disclosure describe systems, methods, apparatuses for wirelessly charging handheld and consumer electronics in wireless power delivery environments. In some embodiments, techniques are described for retrofitting wireless power receivers into existing devices e.g., through wirelessly powered battery apparatuses. For example, the apparatuses discussed herein allow any device that accepts standard form factor batteries to be transformed into a wirelessly powered device. The wirelessly rechargeable battery apparatuses can be applied to any battery form factor including custom or semi-custom battery form factors for mobile phones, laptops, tablet computers, etc. Advantageously, among other benefits, the apparatuses discussed herein overcome the product integration challenges discussed above.
FIG. 2

Communication established

Array(s) sends beaconing schedule to selected wireless receivers and a transmission code

Wireless receiver(s) broadcasts the coded beacon

Array(s) delivers power to the subscribed wireless receiver(s)
START POLARITY CONFIGURATION CYCLE

CONFIGURE ANTENNA(S) BASED ON ANTENNA POLARITY CONFIGURATION

RECEIVE WIRELESS POWER FROM WIRELESS POWER TRANSMISSION SYSTEM

MEASURE WIRELESS POWER RECEIVED

CYCLE COMPLETE?

SELECT OPTIMAL POLARITY CONFIGURATION

DYNAMICALLY CONFIGURE ANTENNA(S) BASED ON SELECTED ANTENNA POLARITY CONFIGURATION

FIG. 15
FIG. 20
WIRELESSLY CHARGEABLE BATTERY APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS


BACKGROUND

[0002] The use of mobile communication devices (or mobile devices), such as personal data assistants (PDAs), cell phones (including smart phones or mobile phones), and tablet computers, is ubiquitous. These devices must be supplied with electricity to function and typically include rechargeable batteries to enable portability. The rechargeable batteries are typically recharged through the use of battery chargers which plug into a port on the mobile device and to an electrical outlet to facilitate the transfer of electrical power. Moreover, in some cases such as with rechargeable AA batteries, a device might be completely dysfunctional when the batteries are removed and placed on an external charger. Consequently, when a mobile device is charging or when batteries are charging, the device essentially becomes tethered to the wall and its portability aspect is lost for the duration of time the battery is recharged.

[0003] Wireless charging functionality can be added to devices through the use of various wireless power receiver components, such as those made and designed by Ossia, Inc. Unfortunately, it is time consuming, difficult and expensive to integrate product enhancements, such as wireless charging functionality, into existing wireless devices as the enhancements can require extensive internal and/or external redesign.

[0004] Accordingly, a need exists for technology that overcomes the problem demonstrated above, as well as one that provides additional benefits. The examples provided herein of some prior or related systems and their associated limitations are intended to be illustrative and not exclusive. Other limitations of existing or prior systems will become apparent to those of skill in the art upon reading the following Detailed Description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] One or more embodiments of the present invention are illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements.

[0006] FIG. 1 depicts a block diagram illustrating an example wireless power delivery environment depicting wireless power delivery from one or more wireless chargers to various wireless devices within the wireless power delivery environment.

[0007] FIG. 2 depicts a sequence diagram illustrating example operations between a wireless charger and a wireless receiver device for commencing wireless power delivery in accordance with some embodiments.

[0008] FIG. 3 depicts a block diagram illustrating example components of a wireless power transmitter (charger or wireless power delivery system) in accordance with some embodiments.

[0009] FIG. 4 depicts a block diagram illustrating example components of a wireless power receiver (client) in accordance with some embodiments.

[0010] FIG. 5 depicts a block diagram illustrating example components of a wirelessly chargeable battery apparatus 500, according to some embodiments.

[0011] FIGS. 6A-6C depict a wirelessly chargeable battery apparatus packaged in a cylindrical form factor, according to some embodiments.

[0012] FIGS. 7A and 7B depict an example wirelessly chargeable battery apparatus packaged in a cylindrical form factor, according to some embodiments.

[0013] FIGS. 8A and 8B depict another example wirelessly chargeable battery apparatus packaged in a cylindrical form factor, according to some embodiments.

[0014] FIGS. 9A-9C depict front perspective views of various example wirelessly chargeable battery apparatuses, according to some embodiments.

[0015] FIGS. 10A-10C depict various additional example topologies of wirelessly chargeable battery apparatuses, according to some embodiments.

[0016] FIGS. 11A and 11B depict a cross sectional top view and a front perspective view, respectively, of an example wirelessly chargeable battery apparatus having a flexible printed circuit board, according to some embodiments.

[0017] FIGS. 12A-12C depict a front perspective view and two cross sectional top views, respectively, of example multi-wirelessly chargeable battery apparatuses, according to some embodiments.

[0018] FIGS. 14A-14C depict an example wirelessly chargeable battery apparatus configured in dimensions that conform to a standard AA type battery, according to some embodiments.

[0019] FIG. 15 depicts flow diagrams illustrating an example process for dynamically selecting an optimal antenna polarity, according to some embodiments.

[0020] FIGS. 16A-16D illustrate various views of an example client (wireless power receiver) packaged in a standard battery form factor, according to some embodiments.

[0021] FIGS. 17A-D illustrate various examples of multi-battery configurations, according to some embodiments.

[0022] FIG. 18 is a diagram illustrating an example battery with integrated wireless charging functionality and variable output voltage, according to an embodiment.

[0023] FIGS. 19A and 19B illustrate an example battery having an integrated wireless charging module and one or more storage cells in a storage module.

[0024] FIG. 20 depicts a block diagram illustrating example components of a representative mobile device or tablet computer with a wireless power receiver or client in the form of a mobile (or smart) phone or tablet computer device, according to some embodiments.

[0025] FIG. 21 depicts a diagrammatic representation of a machine, in the example form, of a computer system within which a set of instructions, for causing the machine to perform any one or more of the methodologies discussed herein, may be executed.
DETALLLED DESCRIPTION

[0026] The following description and drawings are illustrative and are not to be construed as limiting. Numerous specific details are described to provide a thorough understanding of the disclosure. However, in certain instances, well-known or conventional details are not described in order to avoid obscuring the description. References to one or an embodiment in the present disclosure can be, but not necessarily are, references to the same embodiment; and, such references mean at least one of the embodiments.

[0027] Reference in this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the disclosure. The appearances of the phrase “in one embodiment” in various places in the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments. Moreover, various features are described which may be exhibited by some embodiments and not by others. Similarly, various requirements are described which may be requirements for some embodiments but not other embodiments.

[0028] The terms used in this specification generally have their ordinary meanings in the art, within the context of the disclosure, and in the specific context where each term is used. Certain terms that are used to describe the disclosure are discussed below, or elsewhere in the specification, to provide additional guidance to the practitioner regarding the description of the disclosure. For convenience, certain terms may be highlighted, for example using italics and/or quotation marks. The use of highlighting has no influence on the scope and meaning of a term; the scope and meaning of a term is the same, in the same context, whether or not it is highlighted. It will be appreciated that same thing can be said in more than one way.

[0029] Consequently, alternative language and synonyms may be used for any one or more of the terms discussed herein, nor is any special significance to be placed upon whether or not a term is elaborated or discussed herein. Synonyms for certain terms are provided. A recital of one or more synonyms does not exclude the use of other synonyms. The use of examples anywhere in this specification, including examples of any terms discussed herein, is illustrative only, and is not intended to further limit the scope and meaning of the disclosure or of any exemplified term. Likewise, the disclosure is not limited to various embodiments given in this specification.

[0030] Without intent to further limit the scope of the disclosure, examples of instruments, apparatus, methods and their related results according to the embodiments of the present disclosure are given below. Note that titles or subtitles may be used in the examples for convenience of a reader, which in no way should limit the scope of the disclosure. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure pertains. In the case of conflict, the present document, including definitions, will control.

[0031] Embeddings of the present disclosure describe systems, methods, apparatuses for wirelessly charging hand-held and consumer electronics in wireless power delivery environments. In some embodiments, techniques are described for retrofitting wireless power receivers into existing devices e.g., through wirelessly powered battery apparatus. For example, the apparatuses discussed herein allow any device that accepts standard form factor batteries to be transformed into a wirelessly powered device. The wirelessly rechargeable battery apparatuses can be applied to any battery form factor including custom or semi-custom battery form factors for mobile phones, laptops, tablet computers, etc. Advantageously, among other benefits, the apparatuses discussed herein overcome the product integration challenges discussed above.

[0032] In some embodiments, the batteries with integrated wireless charging functionality can include one or more antennas. The antenna placement within the battery can be optimized for power reception performance and can vary based on the type of battery form factor. In some embodiments, antenna placement can be on the edge or exterior of the battery device for optimal performance.

[0033] The embodiments described herein are primarily discussed with reference to AA battery form factors. However, it is appreciated that wireless battery apparatuses are configurable in any battery form factor and can be used in any device that requires a rechargeable or non-rechargeable battery.

1. Example Wireless Power Delivery System
   Overview/Architecture

[0034] FIG. 1 is a diagram illustrating an example wireless power delivery environment 100 depicting wireless power delivery from one or more wireless chargers 101 to various wireless devices 102 within the wireless power delivery environment 100. More specifically, FIG. 1 illustrates an example wireless power delivery environment 100 in which wireless power and/or data can be delivered to available wireless devices 102.1-102.n having one or more power receiver clients 103.1-103.n (also referred to herein as “wireless power receivers” or “wireless power clients”). The wireless power receivers are configured to receive isolated wireless power from one or more wireless chargers 101.

[0035] As shown in the example of FIG. 1, the wireless devices 102.1-102.n are mobile phone devices 102.2 and 102.n, respectively, and a wireless game controller 102.1, although the wireless devices 102.1-102.n can be any (smart or dumb) wireless device or system that needs power and is capable of receiving wireless power via one or more integrated power receiver clients 103.1-103.n. As discussed herein, the one or more integrated power receiver clients or “wireless power receivers” receive and process power from one or more transmitters/chargers 101.a-101.n and provide the power to the wireless devices 102.1-102.n for operation thereof.

[0036] Each charger 101 (also referred to herein as a “transmitter”, “array of antennas” or “antenna array system”) can include multiple antennas 104, e.g., an antenna array including hundreds or thousands of antennas, which are capable of delivering wireless power to wireless devices 102. In some embodiments, the antennas are adaptively-phased radio frequency antennas. The charger 101 is capable of determining the appropriate phases to deliver a coherent power transmission signal to the power receiver clients 103. The array is configured to emit a signal (e.g., continuous wave or pulsed power transmission signal) from multiple antennas at a specific phase relative to each other. It is appreciated that use of the term “array” does not necessarily limit the antenna array to any specific array structure. That
is, the antenna array does not need to be structured in a specific “array” form or geometry. Furthermore, as used herein he term “array” or “array system” may be used include related and peripheral circuitry for signal generation, reception and transmission, such as radios, digital logic and moderns. In some embodiments, the charger 101 can have an embedded Wi-Fi hub.

[0037] The wireless devices 102 can include one or more receive power clients 103. As illustrated in the example of FIG. 1, power delivery antennas 104a and data communication antennas 104b are shown. The power delivery antennas 104a are configured to provide delivery of wireless radio frequency power in the wireless power delivery environment. The data communication antennas are configured to send data communications to and receive data communications from the power receiver clients 103.1-103.n and/or the wireless devices 102.1-102.n. In some embodiments, the data communication antennas can communicate via Bluetooth, Wi-Fi, ZigBee, etc.

[0038] Each power receiver client 103.1-103.n includes one or more antennas (not shown) for receiving signals from the chargers 101. Likewise, each charger 101.a-101.n includes an antenna array having one or more antennas and/or sets of antennas capable of emitting continuous wave signals at specific phases relative to each other. As discussed above, each array is capable of determining the appropriate phases for delivering coherent signals to the power receiver clients 102.1-102.n. For example, coherent signals can be determined by computing the complex conjugate of a received beacon signal at each antenna of the array such that the coherent signal is properly phased for the particular power receiver client that transmitted the beacon signal.

[0039] Although not illustrated, each component of the environment, e.g., wireless power receiver, charger, etc., can include control and synchronization mechanisms, e.g., a data communication synchronization module. The chargers 101.a-101.n can be connected to a power source such as, for example, a power outlet or source connecting the chargers to a standard or primary alternating current (AC) power supply in a building. Alternatively or additionally, one or more of the chargers 101.a-101.n can be powered by a battery or via other mechanisms.

[0040] In some embodiments, the power receiver clients 102.1-102.n and/or the chargers 101.a-101.n utilize reflective objects 106 such as, for example, walls or other RF reflective obstructions within range to transmit beacon signals and/or receive wireless power and/or data within the wireless power delivery environment. The reflective objects 106 can be utilized for multi-directional signal communication regardless of whether a blocking object is in the line of sight between the charger and the power receiver client.

[0041] As described herein, each wireless device 102.1-102.n can be any system and/or device, and/or any combination of devices/systems that can establish a connection with another device, a server and/or other systems within the example environment 100. In some embodiments, the wireless devices 102.1-102.n include displays or other output functionalities to present data to a user and/or input functionalities to receive data from the user. By way of example, a wireless device 102 can be, but is not limited to, a video game controller, a server desktop, a desktop computer, a computer cluster, a mobile computing device such as a notebook, a laptop computer, a handheld computer, a mobile phone, a smart phone, a PDA, a BlackBerry device, a Treo, and/or an iPhone, etc. The wireless device 102 can also be any wearable device such as watches, necklaces, rings or even devices embedded on or within the customer. Other examples of a wireless device 102 include, but are not limited to, safety sensors (e.g., fire or carbon monoxide), electric toothbrushes, electronic door lock/handles, electric light switch controller, electric shavers, etc.

[0042] Although not illustrated in the example of FIG. 1, the charger 101 and the power receiver clients 103.1-103.n can each include a data communication module for communication via a data channel. Alternatively or additionally, the power receiver clients 103.1-103.n can direct the wireless devices 102.1-102.n to communicate with the charger via existing data communications modules. Additionally, in some embodiments the beacon signal, which is primarily referred to herein as a continuous waveform, can alternatively or additionally take the form of a modulated signal.

[0043] FIG. 2 is a sequence diagram 200 illustrating example operations between a wireless charger 101 and a power receiver client 103 for commencing isolated wireless power delivery, according to an embodiment. Initially, communication is established between the charger 101 and the power receiver client 103. The charger 101 subsequently sends beacon schedule information and a transmission code to the power receiver client 103 to facilitate encoding of the beacon signal by the power receiver client 103 for subsequent isolated wireless power delivery by the charger. The charger 101 can also send power transmission scheduling information so that the power receiver client 103 knows when to expect wireless power from the charger. As discussed herein, the power receiver client 103 generates an encoded beacon signal using the transmission code and broadcasts the encoded beacon during a beacon transmission assignment indicated by the beacon schedule information, e.g., BBS cycle.

[0044] As shown, the charger 101 receives the beacon from the power receiver client 103 and decodes the encoded beacon signal using the transmission code provided to the client 103 to ensure that the client 103 is an authorized or selected client. The charger 101 also detects the phase (or direction) at which the beacon signal is received and, once the charger determines that the client is authorized, delivers wireless power and/or data to the power receiver client 103 based the phase (or direction) of the received beacon. In some embodiments, the charger 101 can determine the complex conjugate of the phase and use the complex conjugate to deliver and/or otherwise direct wireless power to the power receiver client 103 in the same direction (or phase) in which the beacon signal was received from the power receiver client 103.

[0045] In some embodiments, the charger 101 includes many antennas; one or more of which are used to deliver power to the power receiver client 103. The charger 101 can detect phases at which the beacon signals are received at each antenna. The large number of antennas may result in different coded beacon signals being received at each antenna of the charger 101. The charger may then determine the complex conjugate of the beacon signals received at each antenna. Using the complex conjugates, one or more antenna may emit a signal that takes into account the effects of the large number of antennas in the charger 101. In other words, the charger 101 emits a signal from one or more antennas in such a way as to create an aggregate signal from the one or
more of the antennas that approximately recreates the wave form of the beacon in the opposite direction.

[0046] As discussed herein, wireless power can be delivered in power cycles defined by power schedule information. A more detailed example of the signaling required to commence wireless power delivery is described now with reference to FIG. 3.

[0047] FIG. 3 is a block diagram illustrating example components of a wireless charger 300, in accordance with an embodiment. As illustrated in the example of FIG. 3, the wireless charger 300 includes a master bus controller (MBC) board and multiple mezzanine boards that collectively comprise the antenna array. The MBC includes control logic 310, an external data interface (I/F) 315, an external power interface (I/F) 320, a communication block 330, and proxy 340. The mezzanine (or antenna array boards 350) each include multiple antennas 360a-360n. Some or all of the components may be omitted in some embodiments. Additional components are also possible.

[0048] The control logic 310 is configured to provide control and intelligence to the array components. The control logic 310 may comprise one or more processors, FPGAs, memory units, etc., and direct and control the various data and power communications. The communications block 330 can direct data communications on a data carrier frequency, such as the base signal clock for clock synchronization. The data communications can be Bluetooth, Wi-Fi, ZigBee, etc. Likewise, the proxy 340 can communicate with clients via data communications as discussed herein. The data communications may be Bluetooth, Wi-Fi, ZigBee, etc.

[0049] In some embodiments, the control logic 310 can also facilitate and/or otherwise enable data aggregation for Internet of Things (IoT) devices. In some embodiments, wireless power clients can access and/or otherwise obtain IoT information about the device in which the wireless power receiver is embedded and provide that IoT information to the wireless charger 300 over a data connection. This IoT information can be provided to an external data interface 315 to a central or cloud-based system (not shown) where the data can be aggregated, processed, etc. For example, the central system can process the data to identify various trends across geographies, chargers, environments, devices, etc. In some embodiments, the aggregated data and/or the trend data can be used to improve operation of devices via remote updates, etc. Alternatively or additionally, in some embodiments, the aggregated data can be provided to third party data consumers in this manner, the wireless charger acts as a Gateway or Enabler for the IoT devices. By way of example and not limitation, the IoT information can include capabilities of the device in which the wireless power receiver is embedded, usage information of the device, power levels of the device, information obtained by the device or the wireless power receiver itself, e.g., via sensors, etc.

[0050] The external power interface 320 is configured to receive external power and provide the power to various components. In some embodiments, the external power interface 320 may be configured to receive a standard external 24 Volt power supply. Alternative configurations are also possible.

[0051] An example of a system power cycle is now described. In this example, the master bus controller (MBC), which controls the charger array, first receives power from a power source and is activated. The MBC then activates the proxy antenna elements on the charger array and the proxy antenna elements enter a default "discovery" mode to identify available wireless receiver clients within range of the charger array. When a client is found, the antenna elements on the charger array power on, enumerate, and (optionally) calibrate.

[0052] Next, the MBC generates beacon transmission scheduling information and power transmission scheduling information during a scheduling process. The scheduling process includes selection of power receiver clients. For example, the MBC can select power receiver clients for power transmission and generate a Beacon Beat Schedule (BBS) cycle and a Power Schedule (PS) for the selected wireless power receiver clients. A graphical signaling representation of an example BBS and PS is shown and discussed in greater detail with reference to FIGS. 6 and 7. As discussed herein, the power receiver clients can be selected based on their corresponding properties and/or requirements.

[0053] In some embodiments, the MBC can also identify and/or otherwise select available clients that will have their status queried in the Client Query Table (CQT). Clients that are placed in the CQT are those on "standby", e.g., not receiving a charge. The BBS and PS are calculated based on vital information about the clients such as, for example, battery status, current activity/usage, how much longer the client has until it runs out of power, priority in terms of usage, etc.

[0054] The Proxy AE broadcasts the BBS to all clients. As discussed herein, the BBS indicates when each client should send a beacon. Likewise the PS indicates when and to which clients the array should send power to. Each client starts broadcasting its beacon and receiving power from the array per the BBS and PS. The Proxy can concurrently query the Client Query Table to check the status of other available clients. A client can only exist in the BBS or the CQT (e.g., waitlist), but not in both. In some embodiments, a limited number of clients can be served on the BBS and PS (e.g., 32). Likewise, the CQT may also be limited to a number of clients (e.g., 32). Thus, for example, if more than 64 clients are within range of the charger, some of those clients would not be active in either the BBS or CQT. The information collected in the previous step continues and/or periodically updates the BBS cycle and/or the PS.

[0055] FIG. 4 is a block diagram illustrating example components of a wireless power receiver (client), in accordance with some embodiments. As illustrated in the example of FIG. 4, the receiver 400 includes control logic 410, battery 420, an IoT control module 425, communication block 430 and associated antenna 470, power meter 440, rectifier 450, a combiner 455, beacon signal generator 460, beacon coding unit 462 and an associated antenna 480, and switch 465 connecting the rectifier 450 or the beacon signal generator 460 to one or more associated antennas 490a-n. Some or all of the components may be omitted in some embodiments. For example, in some embodiments, the wireless power receiver client does not include its own antennas but instead utilizes and/or otherwise shares one or more antennas (e.g., Wi-Fi antenna) of the wireless device in which the wireless power receiver is embedded. Additional components are also possible.

[0056] A combiner 455 receives and combines the received power transmission signals from the power trans-
mitter in the event that the receiver 400 has more than one antenna. The combiner can be any combiner or divider circuit that is configured to achieve isolation between the output ports while maintaining a matched condition. For example, the combiner 455 can be a Wilkinson Power Divider circuit. The rectifier 450 receives the combined power transmission signal from the combiner 455, if present, which is fed through the power meter 440 to the battery 420 for charging. The power meter 440 measures the received power signal strength and provides the control logic 410 with this measurement.

[0057] The control logic 410 also may receive the battery power level from the battery 420 itself. The control logic 410 may also transmit/receive via the communication block 430 a data signal on a data carrier frequency, such as the base signal clock for clock synchronization. The beacon signal generator 460 generates the beacon signal, or calibration signal, transmits the beacon signal using either the antenna 480 or 490 after the beacon signal is encoded.

[0058] It may be noted that, although the battery 420 is shown for as charged by and providing power to the receiver 400, the receiver may also receive its power directly from the rectifier 450. This may be in addition to the rectifier 450 providing charging current to the battery 420, or in lieu of providing charging. Also, it may be noted that the use of multiple antennas is one example of implementation and the structure may be reduced to one shared antenna.

[0059] In some embodiments, the control logic 410 and/or the IoT control module 425 can communicate with and/or otherwise derive IoT information from the device in which the wireless power receiver client 400 is embedded. Although not shown, in some embodiments, the wireless power receiver client 400 can have one or more data connections (wired or wireless) with the device in which the wireless power receiver client 400 is embedded over which IoT information can be obtained. Alternatively or additionally, IoT information can be determined and/or inferred by the wireless power receiver client 400, e.g., via one or more sensors. As discussed above, the IoT information can include, but is not limited to, information about the capabilities of the device in which the wireless power receiver is embedded, usage information of the device in which the wireless power receiver is embedded, power levels of the battery or batteries of the device in which the wireless power receiver is embedded, and/or information obtained or inferred by the device in which the wireless power receiver is embedded or the wireless power receiver itself, e.g., via sensors, etc.

[0060] In some embodiments, a client identifier (ID) module 415 stores a client ID that can uniquely identify the power receiver client in a wireless power delivery environment. For example, the ID can be transmitted to one or more chargers when communication are established. In some embodiments, power receiver clients may also be able to receive and identify other power receiver clients in a wireless power delivery environment based on the client ID.

[0061] An optional motion sensor 495 can detect motion and signal the control logic 410 to act accordingly. For example, when a device is receiving power at high frequencies, e.g., above 500 MHz, its location may become a hotspot of (incoming) radiation. Thus, when the device is on a person, e.g., embedded in a mobile device, the level of radiation may exceed acceptable radiation levels set by the Federal Communications Commission (FCC) or other medical/industrial authorities. To avoid any potential radiation issue, the device may integrate motion detection mechanisms such as accelerometers or equivalent mechanisms. Once the device detects that it is in motion, it may be assumed that it is being handled by a user, and would trigger a signal to the array either to stop transmitting power to it, or to lower the received power to an acceptable fraction of the power. In cases where the device is used in a moving environment like a car, train or plane, the power might only be transmitted intermittently or at a reduced level unless the device is close to losing all available power.

II. Wirelessly Chargeable Battery Apparatuses

[0062] FIG. 5 depicts a block diagram illustrating example components of a wirelessly chargeable battery apparatus 500, according to some embodiments.

[0063] As shown in the example of FIG. 5, the wireless power reception apparatus 500 includes a housing 505, one or more antennas 510, circuitry 520, one or more batteries (or battery modules) 530, a user interface 550, and terminals caps 540a and 540b. The circuitry 520 includes radio frequency (RF) circuitry 522, control circuitry 524, and charging electronics 526. As shown in the example of FIG. 5, the one or more antennas 510 are connected to the circuitry 520 via a connection 511 and the circuitry is connected to the one or more batteries 530 via a connection 521. The circuitry is also connected to the power interface 540 via a connection 541 and to a user interface via a connection 551. The connections 511, 521, 531, 533, and 551 may be traces on a printed circuit board, physical wires, or any other mechanism.

[0064] The housing 505 is configured in dimensions that conform to standardized battery dimensions. Accordingly, the wirelessly chargeable battery apparatus is retrofittable into existing portable electronic devices without redesign of those electronic devices. As discussed herein, the portable electronic device can be any portable or mobile electronic device that is powered by rechargeable or non-rechargeable batteries, e.g., game controllers, remote controls, alarm systems, etc. The portable electronic devices can also be devices with less standardized rechargeable batteries such as, for example, mobile phones, tablet computers, etc. Furthermore, the wirelessly chargeable battery apparatus can include some or all of the components of a wireless power receiver client, the components of which are discussed in greater detail above.

[0065] As discussed above, the housing 505 is configured in dimensions that conform to standardized battery dimensions. The example of FIG. 5 with terminal caps 540a and 540b is not shown to scale. The housing 505 can be configured in cylindrical or non-cylindrical cell battery form factors, camera battery form factors, button cell battery form factors, etc. For example, the standard form factor can be, among other form factors, AA, AAA, C, D, 4.5-volt, 9-volt, Lantern (spring) battery form factors. Furthermore, in some embodiments, the standard form factor can be a form factor that is configured to power mobile devices, including, but not limited to, mobile phone batteries, tablet computer batteries, etc. Example wirelessly chargeable battery apparatuses are shown and discussed in cylindrical form factor. However, as discussed herein, the wirelessly chargeable battery apparatuses are not limited to cylindrical form factors.
The one or more antennas 510 are configured to receive a wireless power signal from a wireless charging system, e.g., a wireless charger. As discussed herein, the wireless power signals can include alternating current (AC) power.

As shown in the example of FIG. 5, the circuitry 520 includes RF circuitry 522, control circuitry 524 and charging electronics 526. The one or more antennas can be located within the housing on one or more printed circuit boards (PCBs), flexible PCBs, embedded on or within the interior surface of the housing 505, and/or embedded on or within the exterior surface of the housing 505 including combinations and/or variations thereof.

Among other functions, the RF circuitry 522 and the control circuitry 524 can perform the various control functions of a wireless power receiver as discussed in greater detail above with reference to FIG. 4. For example, the RF circuitry 522 and/or other components of the circuitry 520 can process the wireless power received via the one or more antennas 510 and convert received wireless RF Power to direct current (DC) power. In some embodiments, the RF Power is alternating current (AC) power. The charging electronics 526 can, among other functions, detect status information of the one or more batteries 530 and/or one or more internal batteries of the portable electronic device to which the housing is attached and control the charging of the one or more batteries 530 based on this information. As discussed herein the one or more batteries 530 can store the DC power. In some embodiments, other storage technology can be used in lieu of or in addition to the one or more batteries. Alternatively, in some embodiments, the wirelessly chargeable battery apparatus may not include a battery but instead directly charge one or more batteries of a portable electronic device to which it is removably attached.

The wirelessly chargeable battery apparatus 500 includes terminal caps 540a and 540b over which power can be exchanged between the battery 530 and/or circuitry 520 and the portable electronic device when wirelessly the wirelessly chargeable battery apparatus 500 is inserted into a battery recess of the portable electronic device.

The user interface 550 can include an interface configured to provide information to a user of a portable electronic device and/or an interface configured to allow the user of the portable electronic device to provide information to the wirelessly chargeable battery apparatus 500. In some embodiments, light emitting diodes (LEDs) can be used to indicate various statuses of the wirelessly chargeable battery apparatus 500. For example, an LED can display a particular color to indicate each battery charging state (e.g., low, med, or high) for battery 530. The user interface 550 can also include one or more user buttons or switches. For example, an ON/OFF switch can be provided on the wirelessly chargeable battery apparatus 500 to control whether or not the apparatus should process wireless power. In other examples, a button can be provided that, once pressed, activates charging of the one or more batteries of a portable electronic device using the energy stored in the one or more batteries 530 of the wirelessly chargeable battery apparatus 500. Other user interface embodiments are also possible.

FIGS. 6A-6C depict a wirelessly chargeable battery apparatus 600 packaged in a cylindrical form factor, according to some embodiments. More specifically, the example of FIGS. 6A-6C illustrate a front perspective, and cross-sectional side and top views of an example wirelessly chargeable battery apparatus 600 packaged in a housing 605 configured in dimensions that conform to a standard AA type battery. The wirelessly chargeable battery apparatus 600 may be wirelessly chargeable battery apparatus 500 of FIG. 5, although alternative configurations are possible.

The wirelessly chargeable battery apparatus 600 includes an antenna 610, circuit boards 622 and 624, a battery 630, and terminal caps 640a and 640b. As shown in the examples of FIGS. 6A-6C, a board-to-board connector 611 connects the circuit boards 622 and 624. As discussed herein, in some embodiments, a single board is utilized and thus no board-to-board connector 611 is needed. Additionally, the circuit boards 622 and 624 can include one or more dielectrics 615 configured to provide isolation. In some embodiments, the circuit boards 622 and 624 comprise printed circuit boards (PCBs) that comprise the dielectric material. The terminal caps 640a and 640b are shown connected to battery 630 via wires 631 and 633, respectively.

FIGS. 7A and 7B depict an example wirelessly chargeable battery apparatus packaged in cylindrical form factor, according to some embodiments. More specifically, the examples of FIGS. 7A and 7B illustrate the example wirelessly chargeable battery apparatuses 700a and 700b having a director or reflector plane 725 on the exterior of the housing 705 and the interior of the housing 705, respectively. As shown in the examples of FIGS. 7A-7B, the wirelessly chargeable battery apparatuses 700a and 700b include the housing 705, at least one antenna 710, control circuitry and antenna/RF circuitry 720, a battery 730 and the director or reflector plane 725.

Director or reflector planes 725 can direct and/or otherwise reflect or modify the antenna transmission and/or reception radiation pattern to increase antenna efficiency. As discussed herein, the antenna efficiency includes both the ability to transmit a stronger beacon signal to a wireless power transmission system as well as the ability to receive more power, e.g., stronger signals, from a wireless transmission system. Furthermore, although the director or reflector plane 725 is shown positioned at the top of the housing 705, the director or reflector plane 725 can be located anywhere on or within the housing 705.

FIGS. 8A and 8B depict another example wirelessly chargeable battery apparatus packaged in cylindrical form factor, according to some embodiments. More specifically, the examples of FIGS. 8A and 8B illustrate the example wirelessly chargeable battery apparatuses 800a and 800b having multiple director or reflector planes 825 on the exterior of the housing 805 and the interior of the housing 805, respectively. As shown in the examples of FIGS. 8A and 8B, the wirelessly chargeable battery apparatuses 800a and 800b include the housing 805, at least one antenna 810, control circuitry and antenna/RF circuitry 820, a battery 830 and the multiple director or reflector planes 825.

As discussed above, the director or reflector planes 825 can direct and/or otherwise reflect or modify the antenna transmission and/or reception radiation pattern to increase antenna efficiency. Although the multiple director or reflector planes 825 are shown either on the exterior or the interior of the housing 805 in the examples of FIGS. 8A and 8B, it is appreciated that other embodiments could include director or reflector planes 825 located and/or otherwise situated both inside and outside of the housing 805.

In some embodiments, one or more director or reflector planes 825 can be included with a sleeve or casing...
that fits over a wirelessly chargeable battery apparatus. The sleeve or casing can include the one or more director or reflector planes 825 on the interior or the exterior of the sleeve or casing including combinations and/or variations thereof.

[0078] FIGS. 9A-9C depict front perspective views of various example wirelessly chargeable battery apparatuses, according to some embodiments. More specifically, the examples of FIGS. 9A-9C illustrate various example antenna configurations or types that can be used on or within a wirelessly chargeable battery apparatus, according to some embodiments. More specifically, the examples of FIGS. 9A-9C illustrate a bowtie antenna configuration 910a, a slot antenna configuration 910b and a dipole antenna configuration 910c, according to some embodiments. The example of FIGS. 9A-9C are shown packaged in a cylindrical form factor, however, it is appreciated that other form factors are also possible.

[0079] The example of FIGS. 9A-9C include housing 905a-905c, antennas 910a-910c, control circuitry and antenna/RF circuitry 920a-920c, and batteries 930a-930c. It is appreciated that the example antenna configuration or types can be configured and/or otherwise embedded onto the exterior of housing 905 or situated and/or otherwise embedded into the interior of the housing 905. The configurations shown with respect to FIGS. 9A-9C are example configurations. Embodiments can include combinations and/or variations of thereof. For example, the slot antenna configuration of FIG. 9B could be situated along the length of the housing 905b as opposed to the width.

[0080] FIGS. 10A-10C depict various additional example topologies of wirelessly chargeable battery apparatuses, according to some embodiments. More specifically, the examples of FIGS. 10A-10C depict cross-sectional top views of example wirelessly chargeable battery apparatuses 1000a-1000c packaged in a housing 1005. In the examples of FIGS. 10A-10C, housing 1005 is configured in dimensions that conform to a standard AA type battery.

[0081] The examples of FIGS. 10A-10C illustrate embodiments of wirelessly chargeable battery apparatuses having multiple radiators, e.g., antennas 1010a-1010c and 1012a-1012c, one on the battery 1030a-1030c side and one on the RF side in communication with antenna/RF board 1022a-1022c. Additionally, the examples of FIGS. 10A-10C illustrate a flexible dielectric 1015a-1015c that is configured to isolate the antenna 1012a-1012c from the battery 1030a-1030c, respectively. In some embodiments, the dielectric 1015a-1015c and/or other dielectrics can be designed and/or otherwise configured to isolate and direct the antenna transmission and/or reception patterns. In some embodiments, PCB boards include a ground plane on one side, e.g., copper plane that acts as ground plane. In the examples of FIGS. 10A-10C, the board antenna/RF circuit boards 1022a-1022c include copper ground planes 1023a-1023c that act as another dielectric to isolate and direct the antenna transmission and/or reception patterns of antenna 1010a-1010c.

[0082] In some embodiments, the batteries 1030a-1030c can be used as ground planes with the use of the flexible dielectric 1015a-1015c. More specifically, the example of FIG. 10B shows the flexible dielectric 1015b wrapped around the battery 1030b. Additionally, as discussed in greater detail with reference to FIGS. 7A-8B, the example of FIG. 10C also includes one or more director or reflector planes 1025.

[0083] FIGS. 11A and 11B depict a cross sectional top view and a front perspective view, respectively, of an example wirelessly chargeable battery apparatus 1100 having a flexible printed circuit board 1120, according to some embodiments. More specifically, the examples of FIGS. 11A and 11B illustrate an example wirelessly chargeable battery apparatus 1100 that includes a spatial controller 1121 which is configured to automatically rotate movable components of the wirelessly chargeable battery apparatus 1100 for optimal antenna configuration.

[0084] The flexible printed circuit board 1120 comprises both control circuitry and antenna/RF circuitry. Additionally, although not shown, the flexible printed circuit board 1120 can include or be in contact with one or more antennas that rotate along with the flexible printed circuit board 1120. In some embodiments, the battery 1130 optionally rotates along with the flexible printed circuit board 1120. Alternatively, the battery 1130 can remain in a fixed position.

[0085] In some embodiments, the spatial controller 1121 comprises a coil or spring that automatically adjusts the movable components of the wirelessly chargeable battery apparatus 1100 such that the one or more antennas are optimally positioned for receiving power. As discussed herein, the optimal position for receiving power is the position in which the most power is received from the power transmission system. In some embodiments, the received power can be processed and used to power the coil or spring. For example, in some embodiments, the coil or spring can be controlled by small voltages and/or sensors.

[0086] In some embodiments, small motors, liquid metals, etc., can be used in place of or in addition to the coil or spring in order to control the orientation of the movable components of the wirelessly chargeable battery apparatus 1100.

[0087] FIGS. 12A-12C depict a front perspective view and two cross sectional top views, respectively, of example multi-wirelessly chargeable battery apparatus 1200a-1200c, according to some embodiments. More specifically, as shown in the examples of FIGS. 12A-12C, the multi-wirelessly chargeable battery apparatuses 1200a-1200c each include two wirelessly chargeable battery apparatuses. The wirelessly chargeable battery apparatuses could any the apparatuses discussed herein, although alternative configurations are possible.

[0088] The multi-wirelessly chargeable battery apparatuses 1200a-1200c include package covers 1200a-1200c, antennas, antenna/RF circuit boards, control circuit boards, and batteries. In the examples of FIGS. 12A-12C, the multi-wirelessly chargeable battery apparatuses 1200a-1200c include package covers that are configured in dimensions that conform to a two standard AA type batteries. More specifically, package covers 1206a and 1206c are shown as rectangular packages while package 1206b is configured to closely mimic the dimensions of the multiple standardized batteries.

[0089] The antennas can be configured internally or externally. In some embodiments, the antennas are embedded and/or otherwise placed on or within the package covers 1206a-1206c for increased surface area. For example, the example of FIG. 12B illustrates antennas 1210b and 1212b embedded and/or otherwise placed on the exterior of the package cover 1206b while the example of FIG. 12C illustrates antennas 1210b and 1212b embedded and/or otherwise placed on the exterior of the package cover 1206b.
while the example of FIG. 12C illustrates antennas 1210c and 1212c embedded and/or otherwise placed on the interior of the package cover 1206c. Alternative configurations are also possible. For example, in some embodiments antennas could be placed and/or otherwise embedded within the package cover. Combinations and/or variations of the discussed embodiments are also possible.

[0090] FIGS. 13A-13D depict various front perspective views and a cross sectional top view, respectively, of example multi-wirelessly chargeable battery apparatus packages 1300a-1300d, according to some embodiments. More specifically, the examples of FIGS. 13A-13D illustrate various example antenna configurations that are embedded and/or otherwise situated on or within a multi-wirelessly chargeable battery apparatus package cover.

[0091] As shown in the examples of FIGS. 13A-13D, the antenna configurations include a multi-bowtie configuration (FIG. 13A), a slot configuration (FIG. 13B), a dipole configuration (FIG. 13C), and a cube antenna structure configuration (FIG. 13D). Other configurations are also possible.

[0092] The cube antenna structure configuration of FIG. 13D includes one or more antennas that are wrapped around the multi-wireless power reception apparatus package. This type of configuration generally radiates in every direction and thus does not require that the package be inserted or otherwise placed in a device in a particular orientation. In some embodiments, each face of the cube antenna structure configuration can be a dynamically configurable antenna. For example, the multi-wirelessly chargeable battery apparatus may include one or more controllers that monitor the antennas and dynamically configure which antennas provide optimal power reception.

[0093] FIGS. 14A-14C depict an example wirelessly chargeable battery apparatus 1400 configured in dimensions that conform to a standard AA type battery, according to some embodiments. More specifically, FIGS. 14A-14C illustrate the wirelessly chargeable battery apparatus 1400 with a two-piece detachable housing.

[0094] Referring first to FIG. 14A which illustrates the wirelessly chargeable battery apparatus 1400 with each of the two-piece detachable housing 1440a and 1440b attached. As shown in the examples of FIGS. 14A-14C, when attached, the housing 1440a and 1440b are circular on one end and hexagonal on the opposite end. The housing 1440a and 1440b is circular near a first terminal cap 1440a and hexagonal near a second terminal cap 1440b. Additionally, as shown in the examples of FIGS. 14A-14C, terminal cap 1440a is circular and terminal cap 1440b is hexagonal.

[0095] As shown in the example of FIG. 14A, the housing piece 1440b includes interfaces 1407 and 1408. Interface 1407 is an external switch which can, for example, enable or disable the wirelessly chargeable battery apparatus 1400, e.g., sleep or awake mode. The interface 1408 can be an indicator interface such as, for example, indicator lights or light emitting diodes (LEDs). In some embodiments, light emitting diodes (LEDs) can be used to indicate various statuses of the wirelessly chargeable battery apparatus 500. For example, an LED can display a particular color to indicate a battery charging state (e.g., low, med., or high). Other user interface embodiments are also possible.

[0096] FIG. 14B illustrates components of the wirelessly chargeable battery apparatus 1400 with the two-piece detachable housing 1440a and 1440b detached. As illustrated in the examples of FIGS. 14A and 14B, the wirelessly chargeable battery apparatus 1400 includes the housing 1405a and 1405b, antenna 1410, RF/Antenna board 1422, control board 1424, a board-to-board connector 1425, a charging/electronics components 1425 (e.g., on RF/Antenna board 1422 and/or control board 1424), terminal caps 1440a and 1440b, battery connections 1421, and a battery 1430.

[0097] FIG. 14C illustrates the wirelessly chargeable battery apparatus 1400 and, more particular, housing 1440a including snap on extrudes 1407 that snap into corresponding latches on housing 1440b to attach and/or otherwise fasten. Other physical connection mechanisms are also possible.

[0098] FIG. 15 depicts flow diagrams illustrating an example process 1500 for dynamically selecting an optimal antenna polarity, according to some embodiments. More specifically, the example of FIG. 15 illustrates an example polarity configuration cycle whereby the optimal antenna polarity can be determined and configured. A wirelessly chargeable battery apparatus can, among other functions, perform the corresponding steps of example process 1500. The wirelessly chargeable battery apparatus can be wirelessly chargeable battery apparatus 500 of FIG. 5, although alternative configurations are possible.

[0099] To begin, at step 1510, the wirelessly chargeable battery apparatus configures the antenna(s) based on a first of multiple antenna polarity configurations or modes. Initially, the wirelessly chargeable battery apparatus configures the antenna polarity to a "default" or base mode. As discussed herein, the wirelessly chargeable battery apparatus includes one or more antennas having configurable polarity. In some embodiments, the polarity is configured by adjusting, e.g., activating or deactivating, antenna feeds or different antennas.

[0100] At step 1512, the wirelessly chargeable battery apparatus receives power from a wireless power transmission system, e.g., wireless charger. At step 1514, the wirelessly chargeable battery apparatus processes the received wireless power and measures a quantity or amount of wireless power received. Alternatively, or additionally, the wirelessly chargeable battery apparatus may measure the signal strength of the received wireless power signals. In some embodiments, the wirelessly chargeable battery apparatus saves and/or otherwise stores the measured power or signal strength measurement in conjunction with the antenna polarity mode.

[0101] At decision step 1516, the wirelessly chargeable battery apparatus determines if the wirelessly chargeable battery apparatus has cycled through each of the antenna polarity modes. If not, the process continues at step 1510 with the wirelessly chargeable battery apparatus configuring the next antenna polarity configuration. However, if the wirelessly chargeable battery apparatus has cycled through each of the antenna polarity modes, at step 1518, the wirelessly chargeable battery apparatus selects an optimal polarity configuration or antenna polarity mode. As discussed herein, the optimal antenna polarity is the polarity at which the wirelessly chargeable battery apparatus receives the most wireless power or the strongest signal from one or more chargers within a wireless power delivery environment. Lastly, at step 1520, the antennas are configured based on the selected antenna polarity configuration if they are not already configured in the selected mode.

[0102] FIGS. 16A-16D illustrate various views of an example client (wireless power receiver) packaged in a
standard battery form factor, according to some embodiment. More specifically, the examples of FIG. 16A-16D illustrate front perspective, top, bottom and side views, respectively, of an example client (wireless power receiver) packaged in a standard AA type battery form factor. As described herein, the client (wireless power receiver) can be packaged in any standard battery form factor including, cylindrical and non-cylindrical cells or batteries, camera batteries, button cells, etc. By way of example, the example client (wireless power receiver) can be packaged in AA, AAA, C, D, 4.5-volt, 9-volt, Lantern (spring), etc.

[0103] One challenge with retrofitting the wireless charging functionality into existing wireless devices is that each wireless device can have a different multi-battery configuration. In some instances, a single battery with integrated wireless charging functionality can be utilized with a dummy cell for a device requiring two batteries (e.g. two AA batteries). However, the multi-battery configurations can require different voltages depending on the type of battery, the number of batteries, and the configuration (e.g., number of batteries in parallel and number of batteries in series).

[0104] FIGS. 17A-D illustrate various examples of multi-battery configurations, according to some embodiments. As discussed above, each wireless device can have different multi-battery configurations requiring different voltages to power the wireless device. By way of example, FIG. 17A illustrates a standard AA cell 1.5V battery. FIGS. 17B and 17C illustrate two configurations of two side-by-side standard AA cell 1.5V batteries where the positive and negative contacts do not align and where they do, respectively. Lastly, FIG. 17D illustrates an example of two standard AA cell 1.5V batteries in series where the configuration provides 3 Volts when measured end-to-end.

[0105] FIG. 18 is a diagram illustrating an example battery 1800 with integrated wireless charging functionality and variable output voltage, according to an embodiment. The example battery 1800 includes antennas 1804a and 1804b, wireless power receiver circuitry (e.g., a client) 1810, and voltage configuration module 1820, and multiple storage cells 1825. In some embodiments, the output voltage of the example battery 1800 can vary based on the configuration of the storage cells 1825. The storage cells 1825 can be configured and/or reconfigurable by a voltage configuration module 1820. The wireless power receiver circuitry (e.g., a client) 1810 can include one or more of the components of a client (wireless power receiver), as described herein.

[0106] In some embodiments, the voltage configuration module 1820 can automatically configure the voltage based on information received from dummy cells. Alternatively, the voltage configuration module 1820 can be configurable/reconfigurable by a user. Other methods of configuration are also possible.

[0107] FIGS. 19A and 19B illustrate an example battery 1910 having an integrated wireless charging module 1915 and one or more storage cells in a storage module 1925. According to the examples of FIGS. 19A and 19B, the wireless charging module 1915 and the storage module 1925 can be packaged in a 9-Volt battery. A front cover 1930 snaps into the base to keep the components in the 9-Volt battery package. In some embodiments, these components can be removable and/or replaceable.

[0108] In some embodiments, multi-battery configurations can include multiple batteries integrated with wireless charging functionality. The multi-battery configurations can include multiple batteries with one or more integrated with wireless charging functionality and one or more comprising batteries that are chargeable/rechargeable via the one or more integrated with the wireless charging functionality.

### III. Example Systems

[0109] FIG. 20 depicts a block diagram illustrating example components of a representative mobile device or tablet computer 2000 with a wireless power receiver or client in the form of a mobile (or smart) phone or tablet computer device, according to an embodiment. Various interfaces and modules are shown with reference to FIG. 20, however, the mobile device or tablet computer does not require all of modules or functions for performing the functionality described herein. It is appreciated that, in many embodiments, various components are not included and/or necessary for operation of the category controller. For example, components such as GPS radios, cellular radios, and accelerometers may not be included in the controllers to reduce costs and/or complexity. Additionally, components such as ZigBee radios and RFID transceivers, along with antennas, can populate the Printed Circuit Board.

[0110] The wireless power receiver client can be a power receiver clients 103 of FIG. 1, although alternative configurations are possible. Additionally, the wireless power receiver client can include one or more RF antennas for reception of power and/or data signals from a charger, e.g., charger 101 of FIG. 1.

[0111] FIG. 21 depicts a diagrammatic representation of a machine, in the example form, of a computer system within which a set of instructions, for causing the machine to perform any one or more of the methodologies discussed herein, may be executed.

[0112] In the example of FIG. 21, the computer system includes a processor, memory, non-volatile memory, and an interface device. Various common components (e.g., cache memory) are omitted for illustrative simplicity. The computer system 2100 is intended to illustrate a hardware device on which any of the components depicted in the example of FIG. 1 (and any other components described in this specification) can be implemented. For example, the computer system can be any radiating object or antenna array system. The computer system can be of any applicable known or convenient type. The components of the computer system can be coupled together via a bus or through some other known or convenient device.

[0113] The processor may be, for example, a conventional microprocessor such as an Intel Pentium microprocessor or Motorola power PC microprocessor. One of skill in the relevant art will recognize that the terms “machine-readable (storage) medium” or “computer-readable (storage) medium” include any type of device that is accessible by the processor.

[0114] The memory is coupled to the processor by, for example, a bus. The memory can include, by way of example but not limitation, random access memory (RAM), such as dynamic RAM (DRAM) and static RAM (SRAM). The memory can be local, remote, or distributed.

[0115] The bus also couples the processor to the non-volatile memory and drive unit. The non-volatile memory is often a magnetic floppy or hard disk, a magnetic-optical disk, an optical disk, a read-only memory (ROM), such as a CD-ROM, EPROM, or EEPROM, a magnetic or optical
card, or another form of storage for large amounts of data. Some of this data is often written, by a direct memory access process, into memory during execution of software in the computer 2100. The non-volatile storage can be local, remote, or distributed. The non-volatile memory is optional because systems can be created with all applicable data available in memory. A typical computer system will usually include at least a processor, memory, and a device (e.g., a bus) coupling the memory to the processor.

Software is typically stored in the non-volatile memory and/or the drive unit. Indeed, for large programs, it may not even be possible to store the entire program in the memory. Nevertheless, it should be understood that for software to run, if necessary, it is moved to a computer readable location appropriate for processing, and for illustrative purposes, that location is referred to as the memory in this paper. Even when software is moved to the memory for execution, the processor will typically make use of hardware registers to store values associated with the software, and local cache that, ideally, serves to speed up execution. As used herein, a software program is assumed to be stored at any known or convenient location (from non-volatile storage to hardware registers) when the software program is referred to as “implemented in a computer-readable medium”. A processor is considered to be “configured to execute a program” when at least one value associated with the program is stored in a register readable by the processor.

The bus also couples the processor to the network interface device. The interface can include one or more of a modem or network interface. It will be appreciated that a modem or network interface can be considered to be part of the computer system. The interface can include an analog modem, isdn modem, cable modem, token ring interface, satellite transmission interface (e.g., “direct PC”), or other interfaces for coupling a computer system to other computer systems. The interface can include one or more input and/or output devices. The I/O devices can include, by way of example but not limitation, a keyboard, a mouse or other pointing device, disk drives, printers, a scanner, and other input and/or output devices, including a display device. The display device can include, by way of example but not limitation, a cathode ray tube (CRT), liquid crystal display (LCD), or some other applicable known or convenient display device. For simplicity, it is assumed that controllers of any devices not depicted in the example of FIG. 21 reside in the interface.

In operation, the computer system 2100 can be controlled by operating system software that includes a file management system, such as a disk operating system. One example of operating system software with associated file management system software is the family of operating systems known as Windows® from Microsoft Corporation of Redmond, Wash., and their associated file management systems. Another example of operating system software with its associated file management system software is the Linux operating system and its associated file management system. The file management system is typically stored in the non-volatile memory and/or drive unit and causes the processor to execute the various acts required by the operating system to input and output data and to store data in the memory, including storing files on the non-volatile memory and/or drive unit.

Some portions of the detailed description may be presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise, as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as “processing” or “computing” or “calculating” or “determining” or “displaying” or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system’s registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the methods of some embodiments. The required structure for a variety of these systems will appear from the description below. In addition, the techniques are not described with reference to any particular programming language, and various embodiments may thus be implemented using a variety of programming languages.

In alternative embodiments, the machine operates as a standalone device or may be connected (e.g., networked) to other machines. In a networked deployment, the machine may operate in the capacity of a server or a client machine in a client-server network environment or as a peer machine in a peer-to-peer (or distributed) network environment.

The machine may be a server computer, a client computer, a personal computer (PC), a tablet PC, a laptop computer, a set-top box (STB), a personal digital assistant (PDA), a cellular telephone, an iPhone, a BlackBerry, a processor, a telephone, a web appliance, a network router, switch or bridge, or any machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine.

While the machine-readable medium or machine-readable storage medium is shown in an exemplary embodiment to be a single medium, the term “machine-readable medium” and “machine-readable storage medium” should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of
instructions. The term “machine-readable medium” and “machine-readable storage medium” shall also be taken to include any medium that is capable of storing, encoding or

carrying a set of instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the presently disclosed technique and

innovation.

[0125] In general, the routines executed to implement the embodiments of the disclosure, may be implemented as part of an operating system or a specific application, component, program, object, module or sequence of instructions referred to as “computer programs.” The computer programs typically comprise one or more instructions set at various times in various memory and storage devices in a computer, and that, when read and executed by one or more processing units or processors in a computer, cause the computer to perform operations to execute elements involving the various aspects of the disclosure.

[0126] Moreover, while embodiments have been described in the context of fully functioning computers and computer systems, those skilled in the art will appreciate that the various embodiments are capable of being distributed as a program product in a variety of forms, and that the disclosure applies equally regardless of the particular type of machine or computer-readable media used to actually effect the distribution.

[0127] Further examples of machine-readable storage media, machine-readable media, or computer-readable (storage) media include but are not limited to recordable type media such as volatile and non-volatile memory devices, floppy and other removable disks, hard disk drives, optical disks (e.g., Compact Disk Read-Only Memory (CD ROMS), Digital Versatile Disks, (DVDs), etc.), among others, and transmission type media such as digital and analog communication links.

[0128] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise,” “comprising,” and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to.” As used herein, the terms “connected,” “coupled,” or any variant thereof, means any connection or coupling, either direct or indirect, between two or more elements; the coupling of connection between the elements can be physical, logical, or a combination thereof. Additionally, the words “herein,” “above,” “below,” and words of similar import, when used in this application, shall refer to this application as a whole and not to any particular portions of this application. Where the context permits, words in the above Detailed Description using the singular or plural number may also include the plural or singular number respectively. The word “or,” in reference to a list of two or more items, covers all of the following interpretations of the word: any of the items in the list, all of the items in the list, and any combination of the items in the list.

[0129] The above detailed description of embodiments of the disclosure is not intended to be exhaustive or to limit the teachings to the precise form disclosed above. While specific embodiments of, and examples for, the disclosure are described above for illustrative purposes, various equivalent modifications are possible within the scope of the disclosure, as those skilled in the relevant art will recognize. For example, while processes or blocks are presented in a given order, alternative embodiments may perform routines having steps, or employ systems having blocks, in a different order, and some processes or blocks may be deleted, moved, added, subdivided, combined, and/or modified to provide alternative or subcombinations. Each of these processes or blocks may be implemented in a variety of different ways. Also, while processes or blocks are, at times, shown as being performed in a series, these processes or blocks may instead be performed in parallel, or may be performed at different times. Further, any specific numbers noted herein are only examples: alternative implementations may employ differing values or ranges.

[0130] The teachings of the disclosure provided herein can be applied to other systems, not necessarily the system described above. The elements and acts of the various embodiments described above can be combined to provide further embodiments.

[0131] Any patents and applications and other references noted above, including any that may be listed in accompanying filing papers, are incorporated herein by reference. Aspects of the disclosure can be modified, if necessary, to employ the systems, functions, and concepts of the various references described above to provide yet further embodiments of the disclosure.

[0132] These and other changes can be made to the disclosure in light of the above Detailed Description. While the above description describes certain embodiments of the disclosure, and describes the best mode contemplated, no matter how detailed the above appears in text, the teachings can be practiced in many ways. Details of the system may vary considerably in their implementation details, while still being encompassed by the subject matter disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the disclosure should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the disclosure with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the disclosure to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the disclosure encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the disclosure under the claims.

[0133] While certain aspects of the disclosure are presented below in certain claim forms, the inventors contemplate the various aspects of the disclosure in any number of claim forms. For example, while only one aspect of the disclosure is recited as a means-plus-function claim under 35 U.S.C. §112, ¶6, other aspects may likewise be embodied as a means-plus-function claim, or in other forms, such as being embodied in a computer-readable medium. (Any claims intended to be treated under 35 U.S.C. §112, ¶6 will begin with the words “means for.”) Accordingly, the applicant reserves the right to add additional claims after filing the application to pursue such additional claim forms for other aspects of the disclosure.

[0134] The detailed description provided herein may be applied to other systems, not necessarily only the system described above. The elements and acts of the various examples described above can be combined to provide further implementations of the invention. Some alternative implementations of the invention may include not only additional elements to those implementations noted above,
but also may include fewer elements. These and other changes can be made to the invention in light of the above Detailed Description. While the above description defines certain examples of the invention, and describes the best mode contemplated, no matter how detailed the above appears in text, the invention can be practiced in many ways. Details of the system may vary considerably in its specific implementation, while still being encompassed by the invention disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the invention should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the invention with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the invention to the specific examples disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed examples, but also all equivalent ways of practicing or implementing the invention.

What is claimed is:

1. A wirelessly chargeable battery apparatus comprising:
a housing configured in dimensions that conform to
standardized battery dimensions;
one or more antennas situated within the housing, the
antennas configured to receive wireless radio frequency
(RF) power from a wireless charging system;
one or more electronic circuit boards situated within the
housing, the one or more electronic circuit boards
configured to convert the received wireless RF power
to direct current (DC) power; and
one or more battery modules configured to store the DC
power.

2. The wirelessly chargeable battery apparatus of claim 1,
wherein the housing comprises the one or more antennas.

3. The wirelessly chargeable battery apparatus of claim 1,
wherein the housing is constructed of a radio frequency (RF)
transparent material.

4. The wirelessly chargeable battery apparatus of claim 1,
wherein the housing includes an external indicator designating
a particular placement of the wirelessly chargeable
battery apparatus in a battery-powered device.

5. The wirelessly chargeable battery apparatus of claim 1,
wherein the housing comprises:
detachable upper and lower cover portions; and
terminal caps situated at each end of the housing, the
terminal caps configured to deliver the converted wire-
less power to a battery-powered device when the term-
inal caps are in contact with battery contact portions
of the battery-powered device.

6. The wirelessly chargeable battery apparatus of claim 1,
wherein at least one of the one or more antennas comprises
a three-dimensional antenna that is constructed using thin
film, copper tape or printed metal.

7. The wirelessly chargeable battery apparatus of claim 1,
wherein the one or more battery modules are used as a
ground plane for at least one of the one or more antennas.

8. The wirelessly chargeable battery apparatus of claim 1,
further comprising one or more reflector or director planes situated on the inner surface or the outer surface of the
housing.

9. The wirelessly chargeable battery apparatus of claim 8,
wherein at least one of the one or more reflector or director
planes is constructed using thin film, copper tape or printed
metal.

10. The wirelessly chargeable battery apparatus of claim
1, wherein at least one of the one or more electronic circuit
boards comprises a flexible printed circuit board (PCB).

11. The wirelessly chargeable battery apparatus of claim
1, further comprising a dielectric configured to isolate the
one or more battery modules from at least one of the one or
more antennas, wherein the dielectric is constructed of a
flexible material.

12. The wirelessly chargeable battery apparatus of claim
1, wherein the electronic circuitry comprises a radio fre-
quency (RF) board and a control board.

13. The wirelessly chargeable battery apparatus of claim
1, wherein the one or more antennas are situated around the
inner perimeter of the housing or around the outer perimeter
of the housing.

14. The wirelessly chargeable battery apparatus of claim
1, further comprising:
one or more output ports or caps configured to provide the
DC power to a battery-powered device.

15. The wirelessly chargeable battery apparatus of claim
1, wherein the standard form factor comprises one of a
cylindrical or non-cylindrical cell battery, a camera battery,
a button cell battery.

16. The wirelessly chargeable battery apparatus of claim
1, wherein the standard form factor comprises one of a AA,
AAA, C, D, 4.5-volt, 9-volt, Lantern (spring) battery.

17. The wirelessly chargeable battery apparatus of claim
1, further comprising:
a voltage configuration module operable to dynamically
configure and reconfigure the output voltage of the
battery based on a multi-battery configuration associ-
ated with a corresponding wireless device.

18. The wireless battery apparatus of claim 17, wherein
the voltage configuration module is operable to detect the
multi-battery configuration.

19. The wireless battery apparatus of claim 17, wherein
the voltage configuration module is operable to receive input
from a user or a charger indicating the multiple-battery
configuration or from one or more dummy batteries to
determine the multiple-battery configuration.

20. The wireless battery apparatus of claim 1, further comprising:
multiple storage cells, wherein voltage configuration
module is operable to configure and reconfigure the
output of the battery by modifying a configuration of
the multiple storage cells.

21. A wirelessly chargeable battery apparatus for an
electronic device, the wirelessly chargeable battery appar-
atus comprising:
a housing configured in dimensions that conform to
standardized battery dimensions;
a wireless power receiver disposed within the housing, the
wireless power receiver configured to receive wireless
power from a wireless charging system, convert the
wireless power to a medium suitable for storage in one
or more battery modules, and store the converted wireless
power in one or more battery modules; and
terminal caps configured to deliver the converted wireless power to the electronic device when the terminal caps are in contact with battery contact portions of the electronic device.

22. The wirelessly changeable battery apparatus of claim 21, wherein the wireless power receiver comprises:
   one or more antennas configured to receive wireless radio frequency (RF) power from a wireless charging system;
   one or more electronic circuit boards situated within the housing, the one or more electronic circuit boards configured to convert the received wireless RF power to direct current (DC) power; and
   one or more battery modules configured to store the DC power.

23. A wirelessly changeable battery apparatus comprising:
   a housing configured in dimensions that conform to aggregate dimensions of multiple standardized batteries each having standardized battery dimensions;
   one or more antennas situated within the housing, the antennas configured to receive wireless radio frequency (RF) power from a wireless charging system;
   one or more electronic circuit boards situated within the housing, the one or more electronic circuit boards configured to convert the received wireless RF power to direct current (DC) power; and
   one or more battery modules configured to store the DC power.

24. The wirelessly changeable battery apparatus of claim 23, wherein the multiple standardized batteries are connected in parallel or in series.

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